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Review

Prospects of hydropower industry in the Yangtze River Basin: China's green energy choice

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ABSTRACT

Energy security is so important especially when green energy choice is urgently in need. With a series of environmental pollution issues caused by burning fossil fuels, China will change in the future in responding to the need of shifting from fossil fuels to green energy. Hydropower resource is abundant with a great developing potential in China, especially the hydropower in the Yangtze River Basin plays a key role in the adjustment of China's energy structure. However, there are many obstacles to its development, including accommodation & consumption problem, environmental pollution & climate change problem, immigration issue etc. China has halted the development of the majority of small and medium hydropower projects, since the hydropower in the Yangtze River Basin also has many disadvantages on its own. This paper summarizes the current situation of the hydropower industry in the Yangtze River Basin, and makes a comprehensive discussion on its development by using Externality Feature Analysis and SWOT Analysis. A series of development proposals from the aspects of institutional, technical, commercial and political are made to help make the hydropower be a better green energy choice, realize the healthy and sustainable development of the hydropower industry in the Yangtze River Basin, and ensure the smooth progress of energy structure adjustment in China.

Contents

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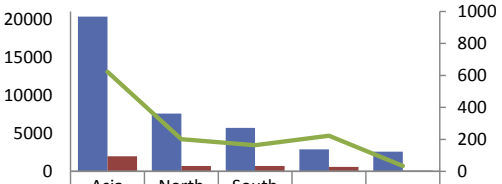
1. Introduction

Green energy is merging into the modern society to create a new infrastructure for "*the Third Industrial Revolution*" that will change the power distribution way in the 21st century [1,2], while the development and industrialization of green energy technology is much admired in many countries to deal with the global environmental problems [3]. Among the green energies, hydropower's contribution and distribution is rather outstanding (Fig. 1). The provision of hydropower achieves very huge economic, social and ecological benefits [4]. By the end of 2016, the global hydropower installed capacity surpassed 1 billion kilowatts with the average development degree of 47%, and generated about 4000 trillion kWh annually [5]. In the developed countries, the development degree of hydropower is relatively high (an average of 60%–95%). On the contrary, it's pretty low in the developing countries (only 39% in China).

China ranks first in the world in terms of water resources reserves, with the technically utilizable installed capacity of 570 million kW and the annual theoretical reserves of 608 million kWh [6]. And it holds a prominent position in the development of green energy in China. Table 1 shows the historical data of China's hydropower installed capacity and the prediction data in 2020. The hydro resource endowment in Yangtze River Basin accounts for roughly 47% of China's total potential capacity of technically exploitable hydropower and ranks first in the world [7]. As China's largest river, the Yangtze River covers one-fifth of the land area of the People's Republic of China (PRC) and its river basin is home to nearly one-third of China's population. In addition, the prosperous Yangtze River Delta generates as much as 20% of the PRC's GDP. Hydropower development along the Yangtze River also has enormous economic benefits in power generation, flood control, irrigation, shipping and the like [12]. It plays an important role in energy security, social stability and ecological protection.

During the "11th *Five-Year Plan*" period (2006–2010), China



	Asia and Pacific	North America	South America	Europe	Africa
Theoretical potential of water resources/TWh	20335	7575	5696	2901	2590
Estimated generation in 2016/TWh	1990	702	709	595	106
Installed capacity/GW	623	201	164	223	34

Fig. 1. Hydropower's contribution and distribution by region.
Sources: International Hydropower Association.

Table 1
China hydropower installed capacity development.

Type	2005(W)	2010 (GW)	2015 (GW)	2020E (GW)
Conventional	110.39	199.12	296.51	340
Large & medium	71.89	140.72	221.51	258
Small	38.5	58.4	75	82
Pumped storage	7	16.95	23.03	40
Total	117.39	216.06	319.54	380

Sources: Authors.

increased hydropower installed capacity by 98.67 million kilowatts, with an average annual increase rate of 13%. During the "12th *Five-Year* Plan" period (2011–2015), the newly-added hydropower installed capacity was 103.48 million kilowatts, with an average annual increase rate of 8.1%. The national hydro installed capacity still maintained a rapid growth although its growth rate slowed down [8]. And during the "13th *Five-Year Plan*" period (2016–2020), China will continue to promote the construction of large-scale hydropower base. In 2016 its growth rate was as low as 4%, the lowest growth rate since 2011 [9]. Hydropower is the superior choice of green energy [10]. By 2020, however, China's hydropower installed capacity is expected to reach 380 million kW, and hydroelectricity production will still remain above 50% of non-fossil energy sources. It can be speculated that hydropower means a lot in China's future energy structure [11,12].

The negative impact caused by hydropower development the Yangtze River Basin has drawn more and more scholars' attention in recent years. WANG Junna (2011) made a series of studies about the impact of hydropower stations on hydrological conditions of the Yangtze River [13]. The reproductive environment of fish, geological activities and other aspects were also proved to be influenced [14–16]. In June 2016, Yunnan and Sichuan provinces along the Yangtze successively issued documents indicating that the construction of small and medium-sized hydropower was suspended and the completed small and medium hydropower plants were no longer expanded [17,18]. This has caused social concern. Later, the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) also issued relevant documents that strictly control the development of small and medium-sized watersheds, small and medium hydropower [8,19]. Judging from the current situation, the prospects of hydropower in the Yangtze River basin are not optimistic, and therefore this paper focuses on the following questions:

(1) What kinds of impacts does the Yangtze River bring to China in all aspects along the river?
(2) What are the disadvantages and challenges that influence the development of the hydropower industry in the Yangtze River Basin at present?
(3) How to achieve the sustainable development of hydropower industry in the Yangtze River Basin in future by making a better Green Energy Choice?

2. Status quo

2.1. Sector situation

2.1.1. Resource endowment

China's hydropower ranks the first around the world with respect to the theoretical exploitability, the technical exploitability and the economical exploitability [7,20]. Fig. 2 shows the location of hydropower along the Yangtze River Basin in China.

The vast Yangtze River Basin locates in the subtropical monsoon climate zone with abundant water. The annual average precipitation is about 1100 mm, and the annual water resources are about 996 billion m^3. The total length of the main stream is more than 6300 m. The upstream basin is located in the southwestern region of China, the junction of terrain ladder. The distribution of water resources in the Yangtze River Basin is generally more in the west than the eastern area for the upstream elevation drop is up to 5400 m. By making Yichang city the watershed, the upstream technical exploitability accounts for 89% of the whole basin. And it's mainly distributed in Sichuan Province, accounting for about 56%. The water resources of the middle and lower reaches are all distributed in all tributaries, accounting for only 11%. Also, the hydropower resources of the Yangtze River rank the first of the thirteen hydropower bases of China [7]. Fig. 3 shows the hydropower divisions in various basins of China.

2.1.2. Industrial scale

In China, 50,000 kW is the standard that distinguishes large and small hydropower plants. By the end of 2016, China's hydropower installed capacity has reached 330 million kilowatts, accounting for 20% of the total installed capacity, second only to the thermal power. From Fig. 4, we can see the development history of hydropower in China. Approximately 46,000 reservoirs have been built in the Yangtze River Basin, with a total capacity of more than 250 billion m^3. Among them, there are 166 large and extra-large reservoirs with a total storage capacity of 190 billion m^3 [21]. Six of the thirteen large hydropower bases of China locate in the Yangtze River basin, including Jinsha River, Yalong River, Dadu River, Wujiang River, the Three Gorges and Xiangxi hydropower base. They account for about 60% of the installed capacity in these large hydropower bases. For now, the level of the whole Yangtze River Basin hydropower development is not very high, and there are still much potential for further development.

Large hydropower stations account for most of the installed capacity of the basin (Fig. 5), of which there are 52 power stations with more than 1 million kilowatts and 107 power stations over 300 thousand kilowatts [22]. During the "11th *Five-Year Plan*" and "12th *Five-Year Plan*" period, the secondary basins like Jinsha River, Mintuo River, Jialing River, Wujiang River and Yibin-Yichang main stream have been developed on a large scale. For now, some large hydropower stations are still under construction or at the pre-planning stage. The lower reaches of the Yangtze River have been basically completed. The hydropower development will enter the second half of the "13th *Five-Year plan*" period and mainly focus on the middle and upper reaches. The hydropower resources remaining to be developed have worse conditions and sensitive factors [23]. It is estimated that by 2020, the total installed capacity of large-scale hydropower stations built in the Yangtze River Basin will reach 132,000 MW, providing about 560 billion kWh of electricity annually [24]. In the future, it is also extremely crucial to carry out rational distribution of small hydropower and pumped storage power stations along the river [25].

2.1.3. Power price

Hydropower is not only the cleaner, lower-carbon energy source, but at a lower cost than thermal power generation. Currently under the relevant provisions of the NDRC, there are three Pricing Mechanisms for hydropower in China, namely "*benchmark price*", "*cost-plus pricing method*", "*backward pricing method*" in power-receiving areas. Currently, the feed-in tariff of newly developed large-scale hydropower projects in the Yangtze River Basin is determined by the average electricity price of the power-receiving area. And there is no unified standard for small hydropower projects in term of the pricing mechanisms. Different provinces in the basin have different price mechanism. However the hydropower

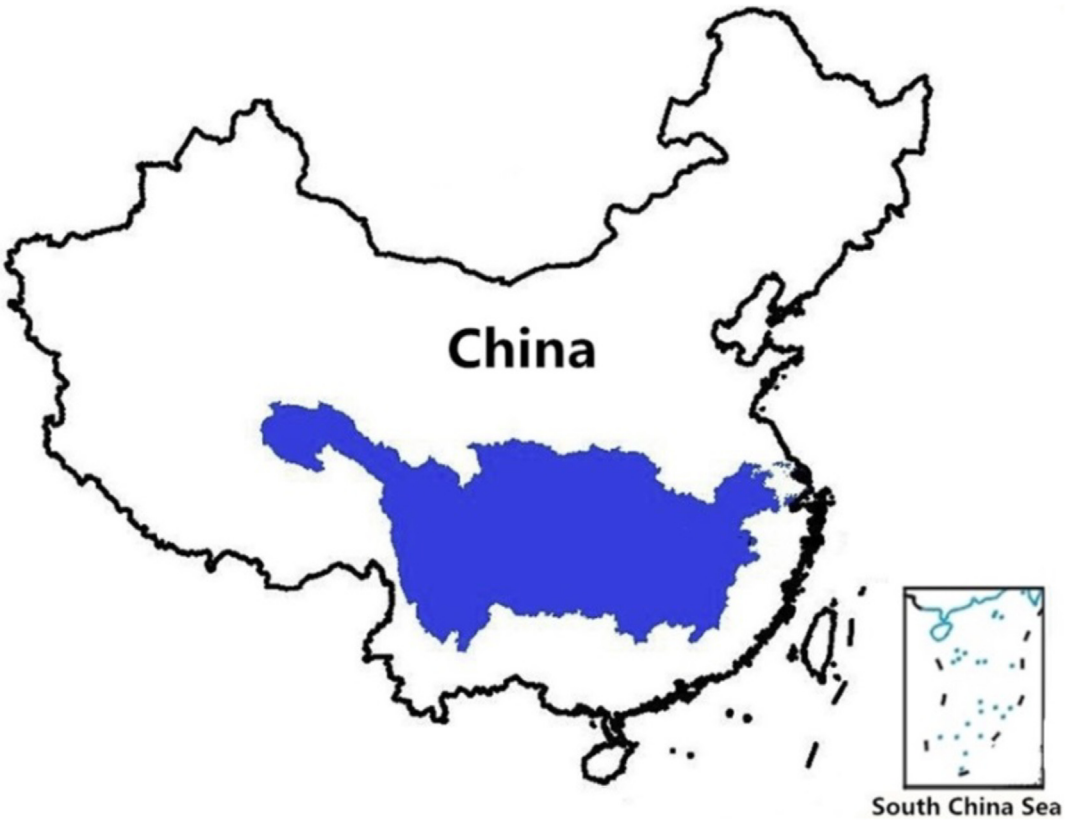


Fig. 2. Location of the Yangtze River Basin.

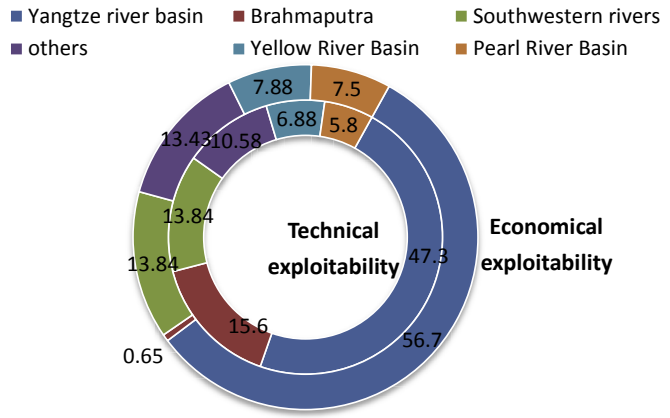


Fig. 3. Distribution of hydropower technical exploitability and the economical exploitability (%).
Source: *"National Hydropower Resource Re-survey Results"*.

prices in these provinces are generally much lower than the local benchmark price. In the new round of electric power system reform, pricing mechanism of hydropower feed-in tariff is supposed to be further improved. Fig. 6 shows the average power price of various types of power generation enterprises in China in recent years.

2.1.4. Consumption

The strategy of "*West -East Power Transmission Project*" is an important action for China to achieve a nationwide optimal allocation of resources and win-win cooperation between east and west. During the "12th *Five-Year Plan*" period, the scale of power flow from West to East reached 140 million kW. And the scale of the power transmission will continue to increase to 270 million kilowatts to solve the hydropower transmission problem during the "13th *Five-Year Plan*" period [26].

During the 11th *and* 12th *Five-Year Plan* period, green energy has developed rapidly under the background of energy structure adjustment in China. China's hydropower sector develops rapidly, but the rapid development is also accompanied by the continuous occurrence of the phenomenon of hydro curtailment. Relevant statistics show that roughly China's wasted hydropower was 20 billion kWh in 2014, 40 billion kWh in 2015 and 80 billion kWh in 2016 [27].

2.2. Policy environment

2.2.1. Support policy

Developing green energies, such as hydropower, solar energy and wind energy, are becoming an important strategic measure to ensure the energy security and address the climate warming. All governments attach great importance to both issues. China proposed that the share of non-fossil energy in China's total energy consumption will reach 15% in 2020 and meet the challenging target of 20% by 2030 [8]. For that reason, China has long attached great importance to the development of hydropower. In view of the development situation in different periods, China has promptly issued corresponding policies to guide the industry to achieve healthy and rational development. Table 2 shows the summary of the policies formulated by the Chinese government in recent years to develop the hydropower industry at different times.

[1] Exchange rate: USDCNY 1 dollar = 6.4678 yuan.

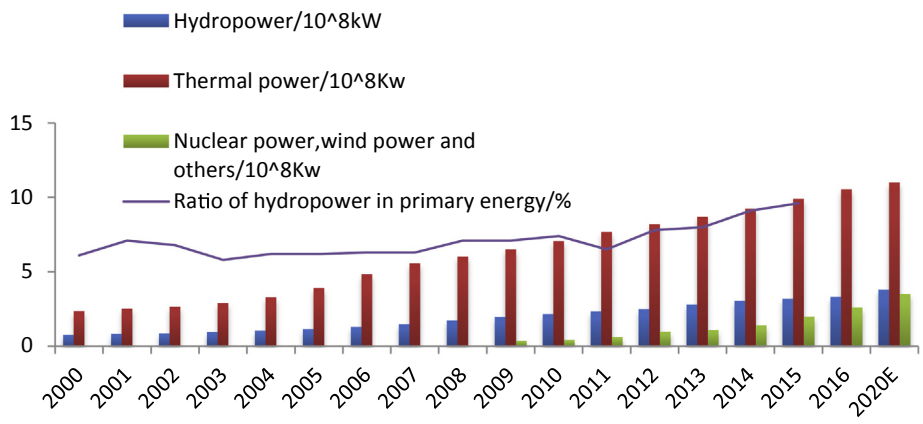


Fig. 4. China electric power production structure.
Source: Authors.

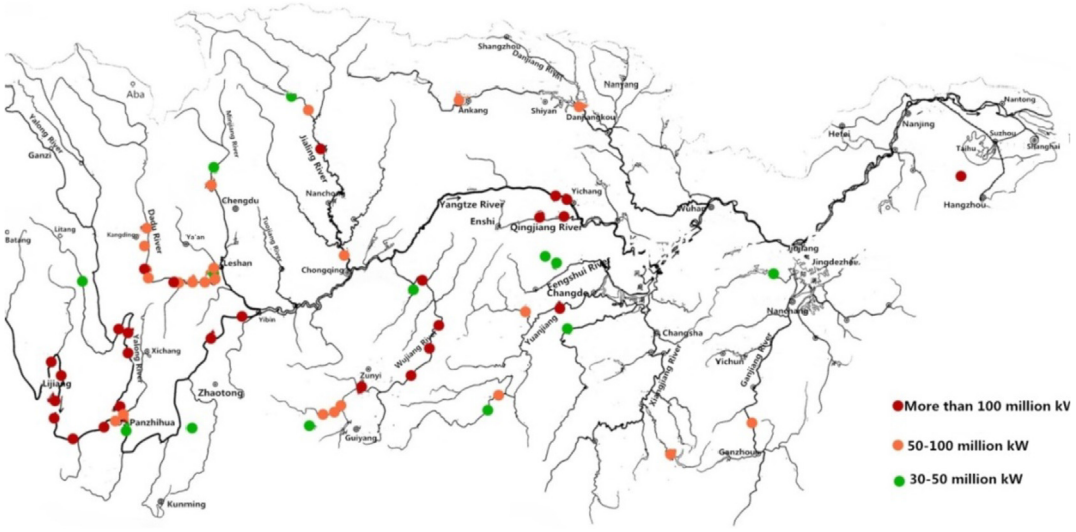


Fig. 5. Distribution of main hydropower stations in the Yangtze River Basin.

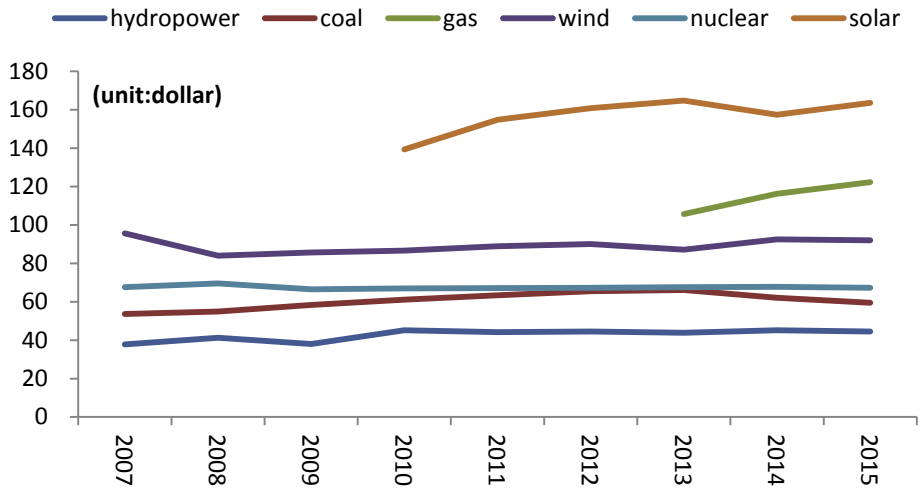


Fig. 6. Average price statistics per MWh.[1]
Source: China Electricity Council.

Table 2
Main documents and announcements about hydropower.

Number	Date	The name of document/announcement	Department
1	Dec.2010	*"Notice on management concerning the regulation of water resource paid use"*	State Ministry of Finance (SMF), NDRC
2	Jan.2011	*"Decision on Speeding up the Reform and Development of Water Conservancy"*	The State Council
3	Mar.2015	*"Opinions on Further Deepening the Reform of Electric Power System"*	The State Council
4	Feb.2016	*"Notice on strengthening the related problems of hydropower management in the basin"*	NDRC
5	Mar.2016	*"Management measures for full guaranteed purchase of renewable energy power generation"*	NDRC
6	Nov.2016	The "13th *Five-year Plan*" of Energy Development, Electric Power Development and Hydropower Development	NEA
7	Sept.2017	*"Notice on Further Promoting Supply-Side Structural Reform and Doing Electricity Demand Side Management in New Situation"*	Six government ministries and administrations
8	Oct.2017.10	*"Notice on the promotion of Southwest hydropower consumption"*	NDRC,NEA
9	Nov.2017	*"The implementation scheme for solving the problem of abandoning water, wind, light"*	NDRC,NEA

2.2.2. Price policy

(1) The price level of hydropower can reflect the state's support on the hydropower industry and the ability of national macro-control. China's electric power system reform is still in the exploratory stage. The current tariff mechanism of hydropower has not been unified. And generally there are three major categories of hydropower stations: large hydropower, small hydropower and pumped storage power plants.

The price policy of large hydropower in China can be traced back to the *"Repayment of Principal and Interest"* issued by the state in the mid-80s of the last century [28]. It determines the electricity price by the approved repayment period of the loan for power generation project. And currently there are three kinds of mechanisms for the formation of hydropower price, as shown in Table 3. On the basis of these three electricity price mechanisms, the NDRC issued the *"Circular on Improving the Formation Mechanism of Hydropower Feed-in Tariff (NDRC Price [2014] No. 61)"*. The document stipulates that the Benchmark Price of hydropower in each province (autonomous region and municipality) should be determined by overall consideration of the electricity market supply and demand trends and hydropower development costs on the basis of average price of provincial power grid enterprises in the province. And as for provinces with high proportion of hydropower, Time-of-Use Price tariff mechanism or classification benchmark tariff mechanism could be carried out according to the function of hydropower station in the power system.

(2) Small hydropower in China is classified as renewable energy. But in fact there is no renewable energy feed-in tariff policy for small hydropower. China's policy on tariff mechanism for small hydropower is imperfect so far. And the guidance document "*Notice on Several Provisions of Small Hydropower Price*" had been issued in 1986. Currently in most provinces the feed-in tariff of small hydropower is dominated by the government mainly on the basis of the Repayment of Principal and Interest mechanism, including the principal and interest of the bank to repay the bank each period, depreciation of fixed assets, fixed expenses, taxes and profits [29].

(3) Due to the special position of the Pumped Storage Power Station in the power system, the government specially formulated the relevant tariff policy in China. In 2014, the NDRC promulgated the *"Circular on Improving the Price Formation Mechanism of Pumped Storage Power Station"*. The document stipulates that before the formation of the electricity market, the pumped storage power station shall implement the "*Two-part tariff*" and the tariff shall be approved at the principle of Reasonable Cost-plus Permitted Revenue.

2.2.3. Tax policy

China has continuously adjusted the tax policy according to the development of the hydropower industry in different periods. The government supports hydropower industry through macroeconomic adjustment to promote the adjustment of industrial structure and the coordinated development of society and economy. Table 4 shows China's current tax policies for different scale hydropower stations.

2.2.4. Financing policy

There are three main ways of financing for energy enterprises:

Table 3
Three major hydropower pricing mechanisms.

Number	Mechanism	Source	Department	Brief content
1	Operating period feed-in tariff	*"Notice on the regulation on electricity price management by State Development and Planning Commission"* (SDPC[2]) (2001)	SDPC	The average feed-in tariff is approved according to the operation period cost of the power generation project
		Interim Measures for feed-in tariff management (2005)	NDRC	According to the economic life cycle of power generation projects, the government department which is in charge of price control shall verify the revenue according to the reasonable compensation cost, and determine the revenue reasonably and calculate the tax according to law
2	Benchmark feed-in tariff	*"Notice of the regulation on electricity price management"* (2001)	SDPC	The feed-in tariff of newly-started power generation enterprises are all changed to be verified on the basis of the average social cost of the same-type advanced generators of the same type in the provincial power grid at the same period
		"Notice on alleviating electricity contradiction and other related issues in the north, South, Central, East, Northeast, Northwest China" (2004)	NDRC	Approve the benchmark price for hydropower in regions with rich hydropower
3	"Market back push" feed-in tariff	*"Notice on the issuance of Three Gorges hydropower station power consumption scheme"* (2001)	SDPC	The feed-in tariff shall be determined by the average price of the power plants of the power-receiving provinces, and fluctuates with the average price level of the power-receiving provinces

Table 4
Summary of China hydropower tax policy.

Number	Type	Documents	Brief content	Department
1	Small Hydro (Stations with 25000 kW and below, including supporting local power grid)	*"Notice on Adjusting the Value - added Tax (VAT) Rate of Agricultural Products and Exempting VAT for Certain Projects"* (1994)	Small hydropower complies with a 6% levying rate of VAT on a simple basis and changed to 3% from July 2014	State Administration of Taxation (SAT)
2	Large and medium-sized hydropower (Including pumped storage power station)	*"Notice on large-scale hydropower corporation VAT policies"* (2014)	Hydropower stations with installed capacity of more than 1 million kW (including pumped storage) adopt tax rebate policy of over a certain percentage	SMF,SAT
		"Notice on Reducing the Taxes and Fees Involved in the Field of Renewable Energy" (2017)	The VAT rate of hydropower stations above 50,000 kW is 13%, hydropower stations with installed capacity of more than 1 million kW (including pumped storage) adopt tax rebate policy of more than 12% of the portion	NEA

bank loans, stock issuance and bond issuance [30]. Hydropower project is the key industry encouraged by the government. The scale of hydropower project investment is huge and the construction period is long. As early as 2005, the central bank began to concentrate on the solution of the financing problem for the energy industry and helped the energy enterprises to expand their financing channels. In 2013, the General Office of the State Council issued *"Notice of the State Council on the plan for the* 12th *Five-Year energy development"*. The document specifies the energy development plan, strengthens the financial support, broadens the financing channels, increases the proportion of direct financing and solves the problems caused by relying solely on bank loans.

According to relevant statistics from NEA, the scale of China's energy industry investment and financing during the "13th *Five-Year Plan*" will reach 930 billion dollars [31]. Green energy accounts for over 480 billion dollars, and the investment in the hydropower industry is expected to be 77 billion dollars. Table 5 shows a series of perfect investment and financing mechanism of energy industry policy issued in China in recent years, including the subsidy policy.

2.2.5. Environmental policy

China's hydropower environmental protection management began in the early 1980s. In the past, the management was mainly based on the Frame Evaluation Guidelines made by the International Commission on Dams [32]. The environmental impact assessment of hydropower projects has been exploring on the basis of the environmental impact evaluation of hydropower projects which has been built. By the late 1980s, large and medium-sized hydropower construction projects were basically incorporated into the track of environmental management. And sound management procedures and environmental impact assessment specifications were established. Table 6 shows the Chinese government's deployment of hydropower development and environmental protection in recent years.

3. Externality analysis

3.1. Economic externality

3.1.1. National level

The Large hydropower project is an important infrastructure.

Table 5
Investment and financing policy of hydropower industry.

Number	Date	Documents	Brief content	Department
1	Mar.2012	*"Notice on Printing and Distributing the Administrative Measures on Discount Funds of Central Government for Capital Construction Loans"*	A special fund from the central budget for capital construction loan interest subsidy	SMF
2	Nov.2014	*"Guidance of the State Council on the investment and financing mechanism in the key areas of innovation to encourage social investment"*	Innovating the investment and financing mechanism, giving full play to the active role of social capital, especially the private capital	The State Council
3	Jan.2015	*"Guidance on encouraging social capital investment in hydropower stations"*	Encourage and guide social investment, standardize and improve the investment environment of hydropower	NEA
4	Apr.2017	*"Opinions on deepening the reform of investment and financing of energy industry"*	Pilot enterprise investment project commitment system; adhere to the decentralization of investment examination and approval authority to match the level and capacity. Conduct pilot projects to identify owners of energy investment projects in a competitive manner	NEA

Table 6
Hydropower industry environmental policy.

Number	Date	Documents	Department
1	Oct.2011	*"Notice on the Interim Measures for the report on the planning of the hydropower planning and the planning of the environmental impact report on the planning and development of the river"*	NDRC, Environmental Protection Department (EPD)
2	Jan.2012	*"Notice on Further Strengthening the environmental protection of hydropower construction"*	EPD
3	Mar.2016	*"Guidance on ecological restoration of river capacity expansion and capacity expansion in rural areas"*	Ministry of Water Resources (MWR)
4	Dec.2016	*"*"13th *Five-Year" planning series of documents"*	NDRC,NEA
5	Dec.2016	*"Guidance on the development of green small hydropower development"*	MWR
6	Jan.2017	*"Notice on the implementation of renewable energy green electricity certificate issuance and voluntary subscription trading mechanism"*	NDRC,SMF
7	May.2017	*"Green small hydropower evaluation standards"*	MWR

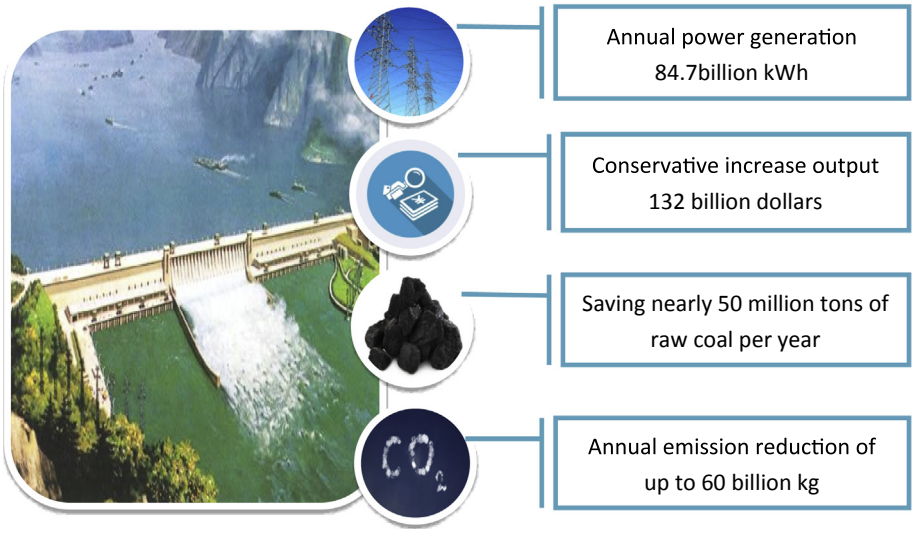


Fig. 7. Benefit overview of the three gorges hydropower station.
Source: Authors.

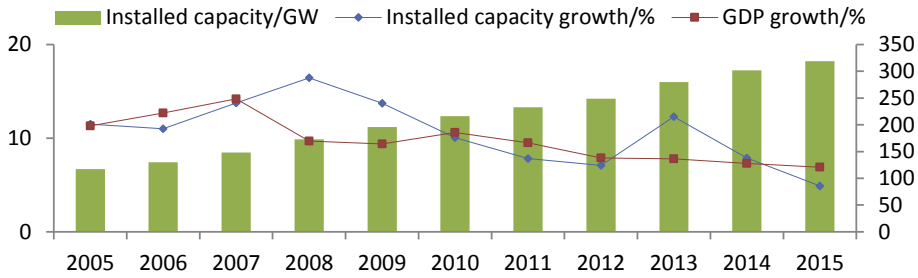


Fig. 8. The growth comparison between China's hydropower installation and GDP.

Many large-scale hydropower projects in the Yangtze River Basin have contributed tremendously to the development of related industries and the optimization of economic structure [33]. Development of hydropower projects requires huge central and local government spending, including investment in construction and installation, equipment purchase costs, loss of cultivated land, resettlement costs, and it will also form a new source of government revenue. It will effectively promote the development of the local economy, and bring about the prosperity of industry and commerce while expand the tax revenue [34]. Its main function, power generation can transmit electricity to local power grid and other power grids simultaneously, including the Central China, the East China, and ensure economic growth both in the power supply areas and the power receiving areas. The Yangtze River Basin has played an important role in realizing the national strategy of "West-to-East Power Transmission" and developing the national economy [35].

Fig. 7 shows the Three Gorges hydropower station's benefit evaluation. And the total installed capacity of the large hydropower station, which is expected to be built up to 13.2 MW in the Yangtze River Basin by 2020, will provide more than 560 billion kWh electricity per year. A rough estimate of economic benefits shows that the GDP from Three Gorges hydropower station will be worth 867 billion US dollars in 2020. Fig. 8 shows China's hydropower installed capacity growth and GDP growth statistics from 2005 to 2015. It can be seen from the figure that they are closely related and have similar trends. The latter's growth has a certain lag compared with the former.

3.1.2. Regional level

Most of the hydropower stations in the Yangtze River Basin are distributed in remote mountainous areas of poverty. The hydropower station makes full use of the surrounding resources, and has a strong impetus to the development of the local society. Generally it also has the benefits of public welfare and functions such as flood control, shipping, irrigation and developing immigration [36]. However the construction and the post-operation of hydropower stations still have some negative impacts on local industries, such fishing industry, mining industry, various factories, enterprises and service industries [37]. But the positive impact overwhelms the negative impact. The hydropower construction mainly promotes the development of the local economy from three aspects, the regional GDP, the social consumption and the income of the residents. Fig. 9 shows Yongshan County's economic index during the construction of Xiluodu Hydropower Station. After the hydropower investment, the growth of Yongshan County's GDP represented a steady upward trend. Obliviously it's faster than the national average for the same period [38].

On the whole, the economic development of the Yangtze River Basin is benefited from the development of the hydropower industry in the Yangtze River Basin. The Yangtze River Economic Belt covers 11 provinces and cities such as Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan and Guizhou. This area covers about 20.5 million km^2 where both the

[2] SDPC is the predecessor of NDRC.

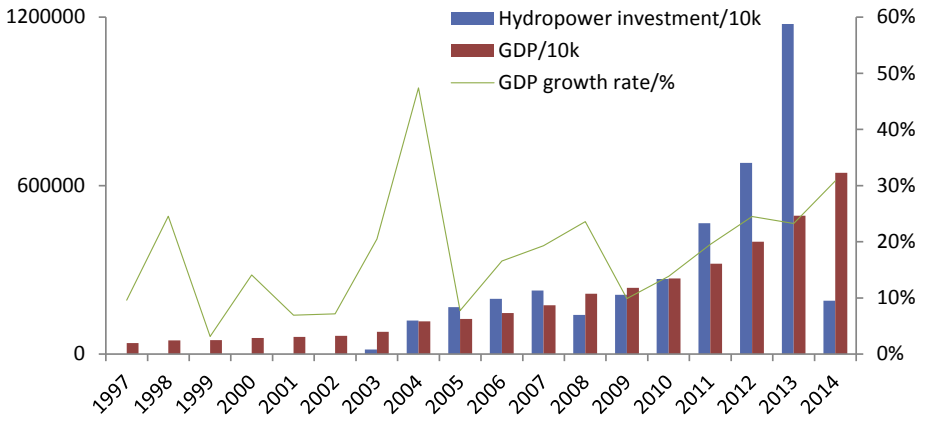


Fig. 9. Comparison of Xiluodu hydropower station investment with Yongshan County's GDP growth.

population and the GDP account for more than 40% of the total population and the total GDP. It is really an important support for the economic growth of those Chinese local areas. And the regional areas are mainly benefited from 3 aspects:

(1) The development of hydropower solves the threat from flooding. The middle and lower reaches of the Yangtze River, which had been threatened by floods throughout history, are able to develop steadily these years.
(2) The hydro projects provide a lot of support for economic development in the basin. Impact arising from large-scale hydro-projects on local area economy is mainly reflected in energy supply, water supply, shipping, etc.
(3) Hydropower development is a practice of low-carbon development. It can reduce fossil energy consumption and promote the development of a low-carbon transition in the Yangtze River economic belt.

3.2. Social externality

3.2.1. Humanistic influence

Due to the complex geographical environment, the hydropower-rich areas are lagging behind with poor development performance in the upper reaches of the basin. The people there used to be relatively conservative and they had less communication with the outside world in the past. Such a relatively closed environment wasn't improved until China's hydropower sector made a difference [39]. First, the local traffic conditions can be improved because of the hydro-sector development. The safe and convenient waterways will help the local make more contacts with the outside world by promoting the flow of materials and information. Second, hydropower development can play the advantages of local resources, such as tourism and planting industry, which helps promote the local economic development to solve the problem of regional poverty effectively. Finally, the local ethnic minorities can further open their mind because the hydropower development helps improve the culture and education conditions in one way or another.

Inevitably, the hydropower development also brings a series of negative effects. It has an impact on the cultural diversity of the local ethnic groups, and on the preservation and development of the natural and cultural heritage.

3.2.2. Project resettlement

Although hydropower development can create enormous social wealth, it also leads to a large number of involuntary resettlement. The best-known example caused by economic development is that resulting from the construction of the Three Gorges Dam in China. Resettlement wasn't considered as an acceptable solution until the problem of imbalanced distribution of benefits and resources caused by the hydro-project intensified social conflicts was solved [40,41]. The consequent problem is the perceived risk resulting from the social contradictions, such as landlessness, unemployment, homelessness, disease, food shortage, loss of right to public resource, social exclusion and marginalization, and disintegration of former social organization [42]. The priority of hydropower development in the Yangtze River Basin is mostly located in the upper reaches which belong to the alpine-gorge area. And the local population density is relatively low [12]. Still, the migration and resettlement in the basin still has a long way to go, even become more difficult to deal with on some extent. The work is so arduous that some problems, such as local conditions improvement, industrial structure optimization and regional economic-social development, must be solved properly with the development of urbanization. The government should take major responsibility in resettlement work. Table 7 shows the resettlement statistics of the major hydropower stations in the Yangtze River Basin. It can be seen that the scale of resettlement involved in the Three Gorges Power Station is much larger than that of other hydropower stations.

3.3. Environmental externality

Hydropower stations also affect the natural resources and ecological environment of the Yangtze River, including the hydrological environment, the climate environment, and the geological activities [11,14].

First, large hydropower station changes the amount of water and runoff into the middle and lower reaches of the Yangtze River. All hydrological fluxes such as sediment, nutrients and water temperature were also influenced [13,14]. And it also changes the geomorphology in the middle and lower reaches of the river, relations between rivers and lakes, and other natural properties. The result is inevitably detrimental to the circadian rhythms of aquatic organisms [43-45].

Second, large-scale water storage reservoir could affect the region's climate. Since the beginning of impoundment in the Three Gorges Reservoir area, there are spatial differences in annual average temperature, annual extreme temperature, annual low temperature, annual precipitation, drought disaster and rainstorm disaster [46]. Besides, the effect on the climate of the whole basin needs to be further studied.

Table 7
Immigration statistics of the main large-scale hydropower station.

Plant name	Three Gorges	Gezhouba Dam	Er Tan	Xiluodu	Xiangjiaba	Baihetan
Installed capacity/GW	224	27.15	33	138.6	64	120
Number of immigrants/10k	139.76	2.85	2.96	6.1	12.5	8.9

Source: Authors.

Finally, due to the accumulation of massive water bulk, the hydropower station construction will have an impact on the geostress of the bottom shell structure in the reservoir area. Discussions on whether hydropower stations can cause geological disasters are still under study.

4. SWOT analysis

In this part, we take the S-Strengths, W-Weaknesses, O-Opportunities and T-threats of hydropower into consideration so as to analyze the development prospects of hydropower and make favorable decision-making plans (Fig. 10). It is also to guide the future development direction of reference.

4.1. Strength

4.1.1. Abundance and low carbon

The water resources of the Yangtze River Basin are abundant. There is a developed water system with numerous tributaries. And six of the thirteen major hydropower bases under China's key planning are located in the Yangtze River Basin. The development of hydropower in the middle and lower reaches of the Yangtze River has been basically completed. The focus in the future will be on the upper reaches of the basin [5]. In the process of its production, water resources and fossil energy are not consumed. At the same time, there is no carbon dioxide and other atmospheric pollutants emitted. Hydropower occupies a very important strategic position in the economic and social development and the adjustment of energy structure in the future.

4.1.2. Economic superiority

The operating costs of hydropower stations are much lower than those of other kinds of stations, and the cost of hydropower electricity is generally lower than other power generation methods [8]. By analyzing feed-in tariff of various kinds of energy in recent years, it could be concluded that the electricity price of hydropower is obviously lower than other power generation.

In addition, hydropower stations not only supply power generation, but also play an important role in other aspects such as water resources allocation, irrigation, shipping and flood control. If the water that flows through the hydropower station just goes away in vain, it will cause huge losses to the hydropower enterprises and the society.

4.2. Weakness

4.2.1. Seasonal precipitation differences

There are seasonal differences in hydropower generation in the Yangtze River Basin due to uneven precipitation throughout the year, hence the power shortage poses a problem during the dry season, especially in winter [15]. Every year hydropower resource is abundant from May to October, the high flow season. In spring and winter, the low flow season, there is a drastic reduction in river water and power generation. Reliable and continuous power supply can't be guaranteed effectively throughout the year. This also limits the development of hydropower and electricity-consuming enterprises. This phenomenon is even more serious for small hydropower stations.

4.2.2. Weak power transmission capacity

Most of the hydropower stations in the Yangtze River Basin are

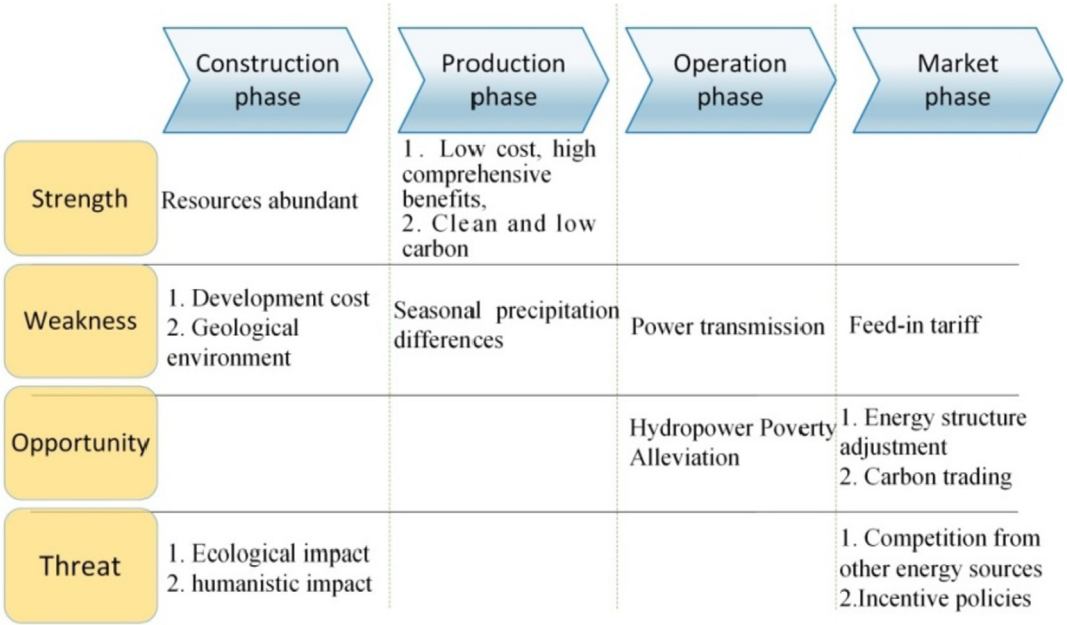


Fig. 10. SWOT analysis on hydropower industry of the Yangtze River.

located in the southwest of China, while the demand for electricity in China is concentrated in the southeastern coastal areas. There is a contradiction between supply and demand in geographical location. In addition, tributaries of the Yangtze River have more hydropower resources than the mainstream and they are widely distributed. There is a problem in how to transmit excess electricity from the southwestern region to the southeastern coastal areas. And recent years this has become a major factor blocking the development of hydropower when the local cannot consume the entire generating capacity.

It is urgent for the government to formulate corresponding countermeasures to solve the problem of interprovincial trade barriers brought by local protectionism and the lagging of power transmission channels construction generated from the contradiction among many power generation enterprises, independent power sale enterprises, and the power STATE GRID.

4.2.3. High social costs

Hydropower development is a multi-faceted and complicated project that requires coordination in planning, site selection, design, acquisition, resettlement, construction, operation and ecological protection [12]. The cost of hydropower development in the Yangtze River Basin has kept increasing in recent years. On the one hand, due to the fact that the upper reaches of the Yangtze River Basin, where hydropower resources have not yet been fully developed, are located in the seismic zone, various geological disasters such as earthquakes, landslides and debris flows occur frequently. This poses a great challenge to the development of hydropower projects. The increasing technology cost in recent years is also a problem. On the other hand, the social costs of hydropower development involving land expropriation, resettlement and the local economic development issues continue to increase recent years. It eventually brings about an increase in the development costs of hydropower projects, which is not conducive to the sustainable and healthy development of the industry.

4.2.4. Dangerous geological environment

Sichuan Province in the upper reaches of the Yangtze River is located at the junction of the Qiangtang block, the Yangzi block and the Songpan-Ganzi block. And it is located in an earthquake-prone band. Considering that since the completion of the Three Gorges project, both the frequency of geological disasters in Sichuan province and the times of hydrologic droughts in the Yangtze River Basin have increased, and therefore the hydropower development has been affected [16].

Take the Three Gorges Project as an Example. Table 8 displays the rough statistical comparison of the earthquakes frequency in western Sichuan around 22 years before and after the construction of the Three Gorges Dam. Based on this, it is speculated that the construction of the Three Gorges Dam has a certain impact on the geological movement in southwest China.

Table 8
Earthquake statistics in Sichuan area before and after three gorges project.

Magnitude	1972–1994		1994–2016	
	Frequency	Ratio	Frequency	Ratio
0–3	104	11.49%	1059	27.35%
3–6	791	87.40%	2803	72.39%
6–8	10	1.10%	10	0.26%
8–10	0	0	1	0.03%
Total	905	100%	3873	100%

Source: China seismic information 2017.

4.3. Opportunity

4.3.1. Energy structure adjustment

China's economic development has come to the stage of “New normal”. The growth rate of energy consumption will obviously be lower than before. Statistics from the relevant statistical agencies show that China's energy consumption increased by 1.3% in 2016, and the growth rate was less than 1/4 of the past ten years' average of 5.3% [9]. But China is still the largest energy consumer in the world. In the new normal context, China ushered in the energy industry restructuring opportunities. The most notable symptom is that coal, as the main energy source in China, achieved negative growth in 2016. The share of coal energy consumption dropped to 62%, a lowest record [9]. And at the same time China surpassed the United States and became the world's largest consumer of green energy. Chinese government pledged to the international community that non-fossil energy consumption will account 15% of energy consumption by 2020. In order to achieve this goal, hydropower is definitely the perfect “green choice” to realize the adjustment of energy structure toward the direction of low-carbon.

4.3.2. Hydropower poverty alleviation

In June 2016, the NDRC and the SMWC released the *"Pilot Projects of Poverty Alleviation Project for Small Hydropower in Rural Areas"*. The document calls for combining the construction of small hydropower stations and poverty alleviation projects in poor counties with abundant hydropower resources to establish a direct and sustainable benefit mechanism for poor households and help them to get rid of poverty. The Decision of the CPC Central Committee and the State Council on *“Winning the Poverty Alleviation and Tackling a Hard Battle”* also pointed out that in the future, the hydropower resources in the poverty-stricken areas should be developed scientifically, rationally and orderly, and the benefit sharing mechanism of water and electricity should be explored to benefit more poor people. The abundant small hydropower resources in the tributaries will benefit from the hydropower poverty alleviation. Development will no longer be at the expense of the of environment destruction with the action.

4.3.3. Carbon trading

Table 9 shows the comparison of various types of power generation carbon emissions. Zero discharge of hydropower compared to coal, oil, natural gas, has the absolute advantage. Since 2011, the NDRC has organized carbon emissions trading pilot projects in seven regions including Beijing. The National Carbon trading Market is about to be established. All power generation enterprises will have to pay a certain amount of cost for their carbon emissions. Because of its low emissions, hydropower development will benefit a lot in the carbon trading market and usher in significant opportunities for development.

Table 9
Carbon emissions from various power generation methods.

Method	CO_2 emissions (t/MWh)
Coal(China)	1.2
Coal(Developed countries)	0.999
Petroleum	0.942
Natural gas	0.439
Hydropower	0
Nuclear power	0
Renewable energy	0

Source: National Environmental Exposure Research Laboratory of US.

4.4. Threat

4.4.1. Ecological impact and humanistic impact

How to reduce the negative impact of hydropower development on the ecological environment is a worldwide scientific problem nowadays. The upper reaches of the Yangtze River, as a high concentration of biological diversity and earthquakes and other geological disasters, is the most ecologically sensitive areas in China [13]. At the same time, more than 6000 species of plants and more than half of the all animal species in China are concentrated here, which is honored as "the world's gene pool of biological genera". It is also home to many ethnic minorities such as Naxi, Dulong and Lisu [34]. In the process of hydropower development, both ecological diversity and ethnic culture will be destroyed if the contradiction can't be solved properly. In recent years, the society has paid more and more attention to the protection of the Yangtze River basin. The balance between development and protection in China is still at the exploratory stage. It is necessary to correctly understand the loss of ecological costs caused by the development.

4.4.2. Multitudinous competitors

The share of hydropower in green energy has decreased from 80% in 2011 to 66% in 2016. This is precisely because of the rapid development of wind, solar and other renewable energy sources. The total coal-fired power installed capacity, including the under-constructed ones, has reached as high as 1.2 billion kW. In the context that China's power industry has emerged an oversupply market scene, many provinces still keep building thermal power plants for the economic development in their respective provinces.

Hydropower development is subject to many restrictions recently. In 2016, China's hydropower consumption increased by only 4%, the lowest growth rate among the past 11 years [9]. During the "13th *Five-Year Plan*" period, the total new coal-fired power generation capacity will still be estimated as high as 200 million kilowatts. The increment of China's coal-power capacity is estimated to be 1.43 times larger than the sum of all renewable energy sources [26]. Future prospects of the hydropower industry in the Yangtze River Basin are going to face fierce competition.

4.4.3. Lack of incentives

Hydropower is arguably the world's most important green energy [25]. Hydropower is the common choice of the developed countries. The incentive policies for the hydropower industry in China are still relatively imperfect compared with the developed countries.

In fact, China's hydropower industry has not begun until after the Reform and Opening-up (1978). After the "10th *Five-Year*" golden period (2001–2005), China's hydropower industry suffered setbacks in "11th *Five-Year*" and "12th *Five-Year*" period. Table 10 shows the main countries' hydropower incentive policies comparison in the world. How to truly implement and realize the policy of active development of water and electricity is an urgent matter.

5. Choice and scheme design

In order to give full play to the advantages of the Yangtze River hydropower and help China make a more scientific and rational choice of green energy, the paper proposes a sound plans for hydropower in four aspects (Fig. 11).

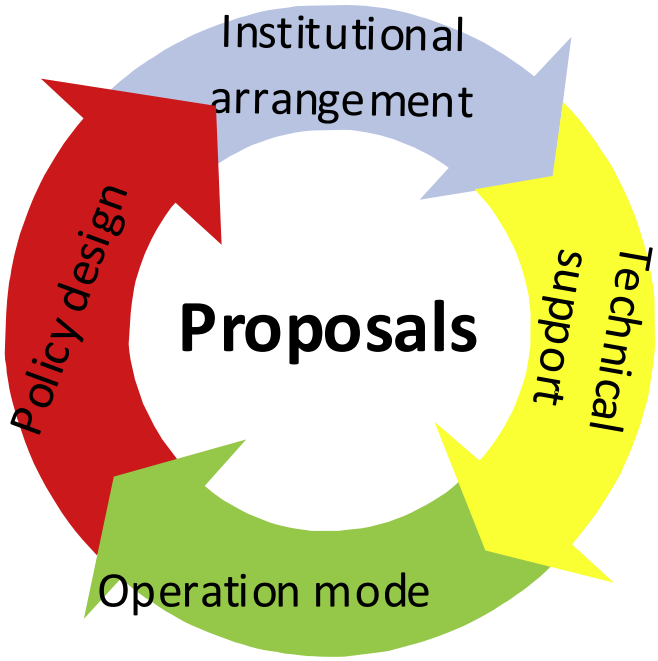


Fig. 11. Hydropower developing proposals.

5.1. Feasibility analysis

Based on the SWOT strategy analysis, the feasibility analysis is as follows:

5.1.1. Market feasibility

China's thermal power industry has gone through the phases of rapid development in the last decade, however the excessive enthusiasm of power plant investment is making the overcapacity in China's thermal electric power industry. 2015, when the total power consumption growth, the thermal power generation growth and the utilization hours of thermal plants reached the lowest levels in recent forty years, became the turning point of China's thermal power industry [47]. The lag of investment, planning, construction and operation of thermal power plants affects the national hydropower industry partially in recent years. In the process of energy structure adjustment, it is foreseeable that the hydropower will gradually replace some of the thermal power in China, especially in the Yangtze River Basin. The future electricity market will also develop in a low-carbon and clean direction. With the help of the *"Energy Internet"* and the *"Belt and Road"* strategic plan, hydropower in the Yangtze River Basin is expected to usher in a larger domestic market, and even in the foreign market.

Table 10
Comparison of hydropower incentives policy among major countries.

Number	Country	Quota Obligation	Repurchase price/Feed-in Tariffs	Tradable Green Certificates	Financial incentives
1	EU	Implemented in 7 member countries	Implemented in 18 member countries	✓	✓
2	US	Implemented in 30 states	None	✓	30% tax credits and subsidies
4	Japan	✓	✓	✓	✓
5	China	None	None	In the early implementation	VAT more than 8%-12% partial subsidy

5.1.2. Technical feasibility

So far, less than one-third of the hydropower resources in the Yangtze River Basin have been developed. The abundant hydropower resources and the suitable geographical environment are the potential necessary conditions for hydropower development in the future. China's hydropower technology has made major breakthroughs in the past few years, and leads the world nowadays. With the support of better "Planning System" and the development direction of "Multi Energy-mix", the negative impact on the environment can be greatly reduced. Meanwhile, the up-and-coming leading hydropower station will make it possible that the joint power dispatching between hydropower stations provides compensatory improvement functions for the downstream small hydropower stations. The obstacles of seasonal precipitation differences and the chaos of hydro curtailment will be solved in the future.

5.1.3. Economic feasibility

The hydropower station needs huge investment in the early stage and long investment recovery period, but the operating cost is low. As a clean energy source, hydropower has an absolute advantage in feed-in tariff. The introduction of "Tradable Green Certificates system" will guide the whole society to consume more hydropower, which makes the benefits more impressive for the investors, and attracts the diversified power generation enterprises or investors. Market-oriented development of hydropower sector will improve the economic efficiency of the electricity market, and suppress irrational investment to bring rationality and transparency to power market. A reasonable Renewable Portfolio Standard for hydropower is not only a critical tool to achieve coordinated development between the conventional energy and new energy, but also determines the future benefits for hydropower investors.

5.1.4. Policy feasibility

Energy poverty alleviation is an important strategic task in the current period in China. The economic and social development of Tibet, Yunnan and Sichuan in the upper reaches of the Yangtze River is lagging behind, with poor infrastructure and low energy demand. Developing local hydropower resources is one of the most convenient ways to turn resource advantages into economic advantages. Constructing some hydropower stations could bring huge investment, stimulate employment and increase people's income in remote mountain areas. In addition, China has already had enough power plants to meet current power needs [48], and there is no need to build extra thermal power plants. The only task for China's electric power sector is to fulfill the promise of *"the Paris Agreement"*. Undoubtedly, hydropower becomes one of the important options and China's Green Energy Choices. It is also feasible for the government to introduce some incentive policies.

5.2. Institutional arrangement

5.2.1. Planning system

The original intention of developing hydropower is to develop green energy. In order to solve a series of ecological problems and social problems caused by hydropower, the establishment of a sound planning system (Fig. 12) is important. Then the hydropower of the Yangtze River could be a better green energy choice.

At the site selection stage, the government should give full consideration to the complicated geological conditions of the local area, set up an expert research team, study the feasibility of dam construction, and publicize the research results finally. The goal is to make the optimal site design that minimizes the loss of geological disasters. Relevant departments should fully study the dispatching status of river basin water resources and rationally construct a hydropower station that is in line with flood control, water storage, irrigation and shipping and other comprehensive benefits.

At the design stage, combined with the current environmental impact assessment system for hydropower stations, the design with less resettlement should be designed to reduce the cost. For the latter part of the natural restoration of ecological issues, plans and solutions need to be made in advance to achieve ecological balance, such as the proliferation of local aquatic fish plan, soil and water conservation plan.

At the construction stage, great importance should be attached to the quality of engineering construction, design reasonable construction plan, carry out construction work in an orderly way, and cooperate with the local government to solve the problem of economic development in reservoir area, so as to solve the problem of resettlement.

At the operation stage, the enterprises must conscientiously carry out the operation and management requirements of the river basin, give full play to the economic and social benefits of the hydropower station, and closely monitor the ecological problems in the reservoir area at the same time, and do well in the work of ecological restoration and protection. This stage is of great importance in the hydropower green evaluation system.

5.2.2. Hydroelectric poverty alleviation

During the "13th *Five-Year Plan*", China will enter the decisive stage in poverty alleviation plan. The upper reaches of the Yangtze River Basin provinces such as Sichuan, Yunnan, Qinghai and Tibet, are contiguous poverty-stricken areas. China urgently needs to improve the establishment of hydropower poverty alleviation

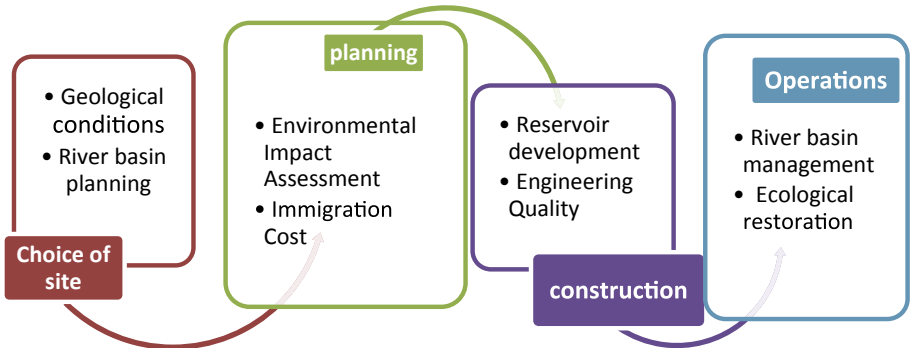


Fig. 12. Planning system of hydropower.

mechanism now.

(1) By summing up the Pilot Project of Poverty Alleviation for Hydropower and the Experience of Photovoltaic Poverty Alleviation Project, it needs to formulate a programmatic document on the national level to guide all regions to achieve accurate, effective poverty alleviation.
(2) The government should explore the mechanism of interest sharing as soon as possible from various aspects, such as employment arrangement during hydropower operation, land acquisition by hydropower, income alleviation and stock quantization, so as to achieve effective poverty alleviation and make the whole society share the fruits of development.
(3) On the one hand, the special funds for Hydropower Poverty Alleviation in poor areas should be implemented. On the other hand, the government should give preferential policies such as financing, loans, taxation and other related policies, so as to help the development of small hydropower in the Yangtze River Basin.
(4) While actively encouraging local consumption, the government should implement the supportive feed-in policies and the supportability purchase plan so as to ensure the smooth development of hydropower poverty alleviation work.

5.2.3. "Belt and Road" transnational power grid

The current trend of power system is grid interconnection. China and its neighboring countries such as Mongolia and Russia have mature models and experiences of successful bilateral power trade. As shown in Fig. 13, the hydropower-rich areas in the upper reaches of the Yangtze River Basin belong to both the Yangtze River Economic Belt and the Silk Road Economic Belt. And they have excellent geographical advantages. The problem of electricity consumption and transportation is a major factor restricting its development.

Focusing on the proposal of the "*Belt and Road*", while China's power technology is going global, China should consider sending extra surplus hydropower resources in the upper reaches of the Yangtze River to these power shortage countries in Southeast Asia, such as India, Myanmar, Pakistan and other countries. It will increase the new energy diplomacy and promote the healthy development of hydropower in China, so that China will fully develop in the field of energy development and international cooperation.

5.2.4. Tradable Green Certificates system

On July 1st, 2017, China started to implement the "Tradable Green Certificates" system, and implemented the voluntary subscription system at an early stage. The current "Green Card Transaction" is an e-Cert with a unique identification code for per megawatt hour of non-water renewable energy on-grid electricity from a power generation company. The purpose is to guide green consumption, to reflect the environmental benefits of clean renewable energy, and to address the funding gap for renewable energy subsidies. And it currently applies to land-based wind power, photovoltaic power generation enterprises (except the distributed PV).

Small hydropower, as an internationally recognized clean and renewable energy source, can be managed with appropriate technical measures to minimize the negative impacts. Therefore, small hydropower should be considered in this transaction field while establishing the status of small hydropower in "*Renewable Energy Law*".

However the "Tradable Green Certificates" practiced in China is

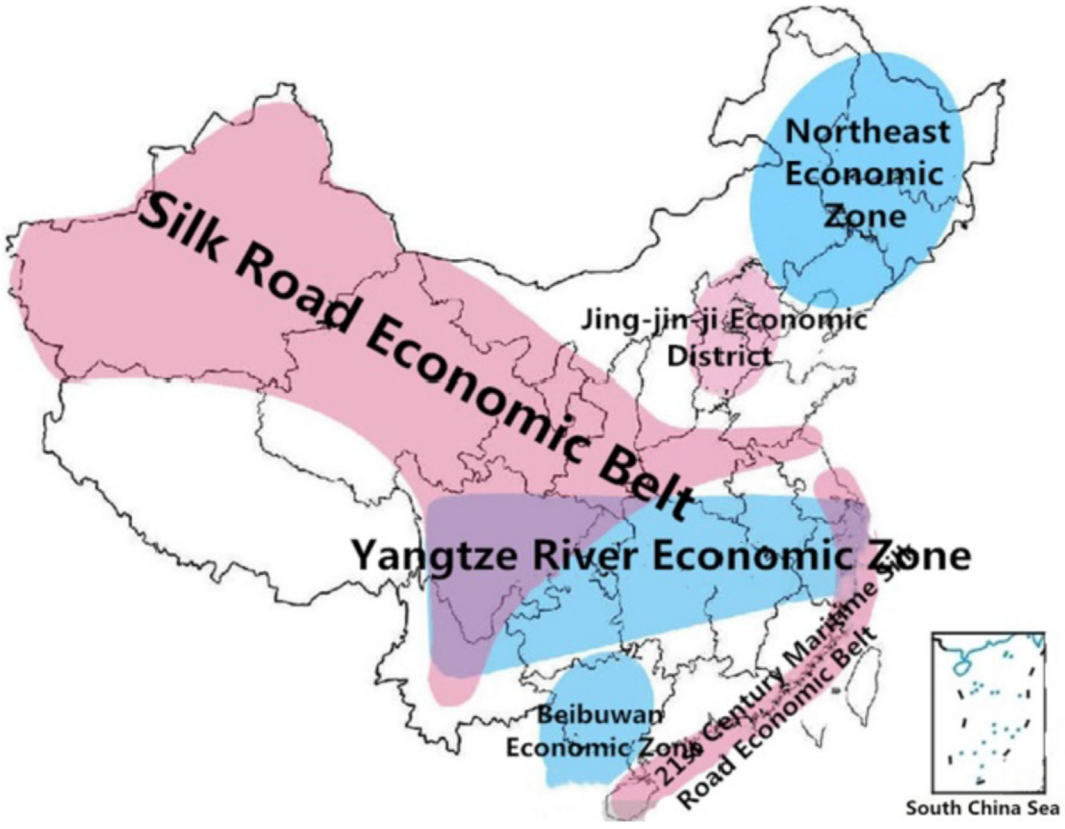


Fig. 13. Geographical advantages of the Yangtze River Basin.

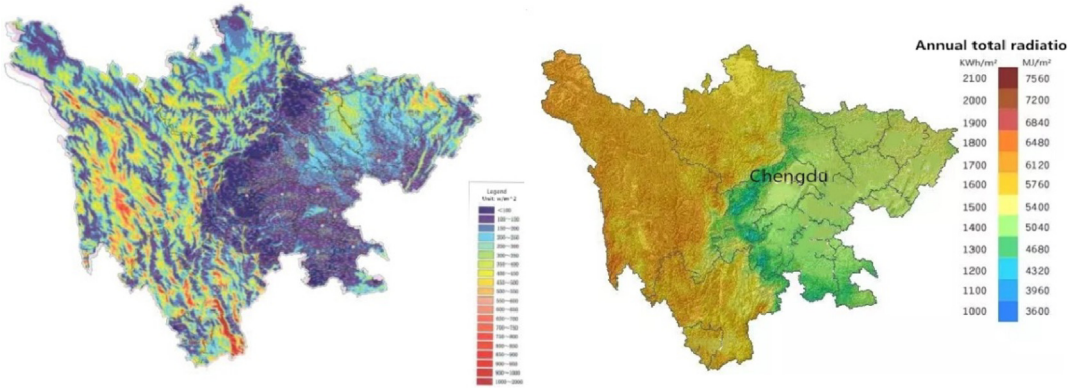


Fig. 14. Distributions of wind energy (left) and solar energy (right) resources in Sichuan Province.

still not perfect so far. Since the cost of new energy such as wind power and electricity varies a lot, its price system needs to be consummated as the core factor. The future introduction of small hydropower also needs to be based on the actual situation of different power plants and form the corresponding green certificate pricing mechanism with consideration of construction, maintenance, power generation, environmental investment and depreciation costs.

5.3. Technical support

5.3.1. Multi Energy complementary

Due to its declining cost and abundant reserves, China's wind power and solar power have enjoyed rapid growth and far exceeded that of hydropower. The scale of wind power and solar power generation are expected to reach 210 million and 160 million kilowatts by 2020 respectively. Hydropower-rich area in the upper reaches of the Yangtze River–Sichuan Province has abundant wind and solar energy resources. The theory of wind energy reserves can be developed about 48.5 million kW, the actual development of 20 million kW, while the corresponding solar energy resources are 100 million kW and 40 million kW. Specific distribution is shown in Fig. 14.

Wind power and solar power generation are affected by the alternation of day and night and the impact of weather changes [45]. They both have the shortcomings of intermittency, randomness and volatility, and the annual utilization hours are relatively low. Hydropower is subject to water regulation and seasonal changes. Hydropower can make a good complementarity with them, adjust the active power output of photovoltaic and wind power generation through the quick adjustment ability of hydrogenerating set to achieve a smooth power generation curve and improve the power quality. At the same time, it can also solve the scale problem of small hydropower to meet the requirements of access to the transmission network, and make up for the constraints of hydropower dispatching and seasonal changes.

Taking the current limitations of the development of large-scale energy storage technology into account, pumped storage plays a dominant role in energy storage. Combining the rich water resources in the upper reaches of the Yangtze River and the geographical advantages of hills, it is feasible to explore a joint development mode of wind power, solar power plants and pumped storage power stations in the future. Pumped storage power stations can store large amounts of excess electricity during low troughs and generate electricity during peak hours. This can also improve the stability of the power system.

In a word, the combined operation (Fig. 15) of wind power, solar power, hydropower and pumped storage power stations is of great significance to the future hydropower industry in the Yangtze River Basin.

5.3.2. Energy internet

Energy transmission, as the most basic function of the energy Internet, can optimize the distribution of energy. And electric is the most important way of energy transport in the Energy Internet, as its speed is close to light.

With the help of energy internet, the problem of hydropower consumption can be solved, and at the same time, it helps to carry out the interchange of hydropower and thermal power, generation rights trade within the entire energy internet and promote China's energy structure adjustment. Hydropower access is also extremely beneficial to the development of the energy Internet due to its installed capacity and regulatory capacity. The advancement of energy Internet requires the matching of transmission channel construction. So for stations newly started or under construction, the relevant departments should plan ahead for the energy market to ensure the full utilization of water resources.

Local consumption is still the first choice of hydropower in the future. With the help of electricity price, peak and valley electricity price and carbon trading, it can excavate the demand for local electricity and promote the replacement of electricity in heat power, steel and cement industries, and encourage electrolytic aluminum, chemical industry and other Energy-consuming industries shift to expand local electricity demand.

5.4. Operation mode

The feed-in tariff of small hydropower in Yangtze River basin has never been guaranteed, and it's far less than the benchmark price of thermal power, even as low as 35 dollars per MWh. On the one hand, this has seriously damaged the legitimate rights and interests of hydropower enterprises. On the other hand, it violated the laws of market economy and the relevant laws and regulations. Along with China's new round of electricity market reform, the sales side has been open. Small hydropower enterprises can set up federations and supply electricity jointly. On this basis, we can integrate the concept of “sharing economy” to establish a shared platform (Fig. 16).

Robin Chase defined the “sharing economy” as three elements: overcapacity (idle resources) + sharing platform + participation of everyone [46]. Among these three factors, the lack of the Yangtze River hydropower industry is the sharing platform. This new economic model (Fig. 16) will organically link these three elements and change the current structure of supply and demand before**.** It can

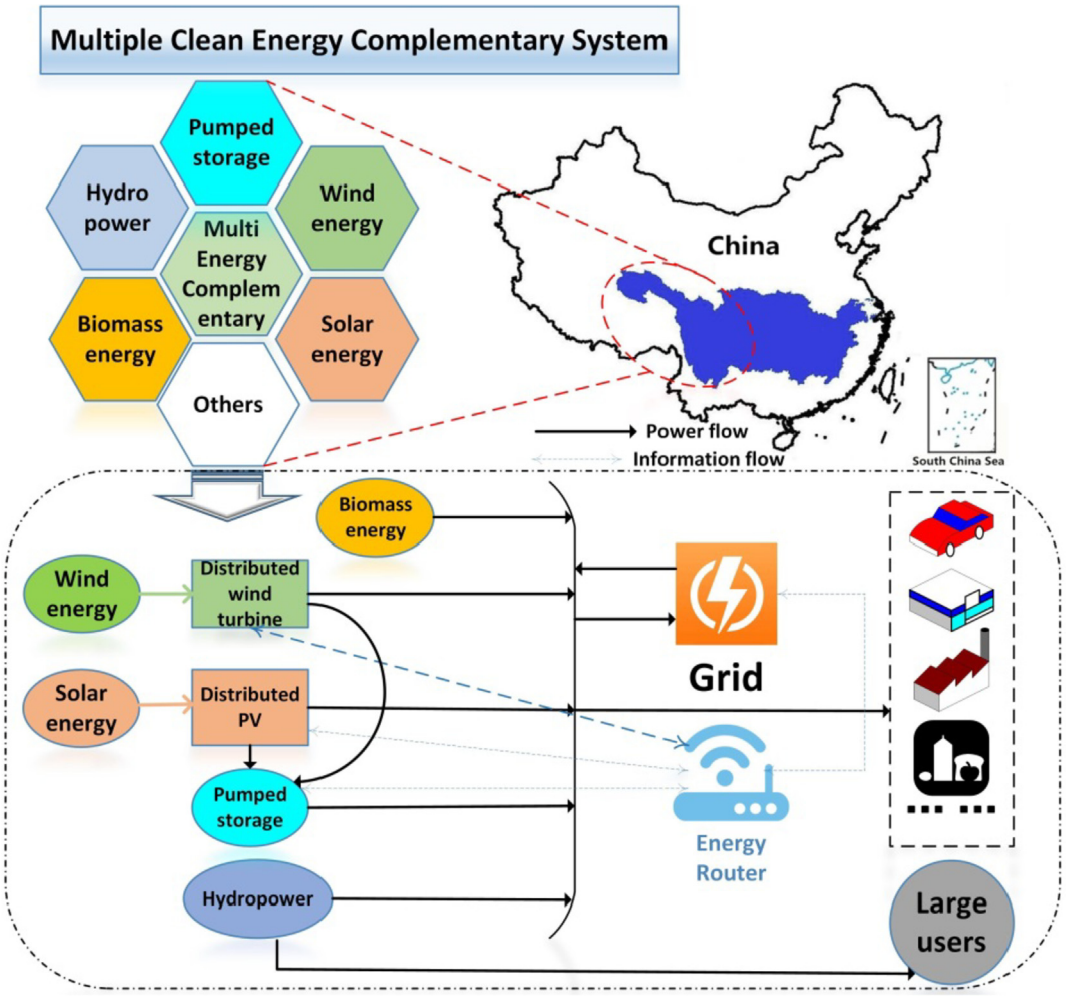


Fig. 15. Multiple clean energy complementary system.

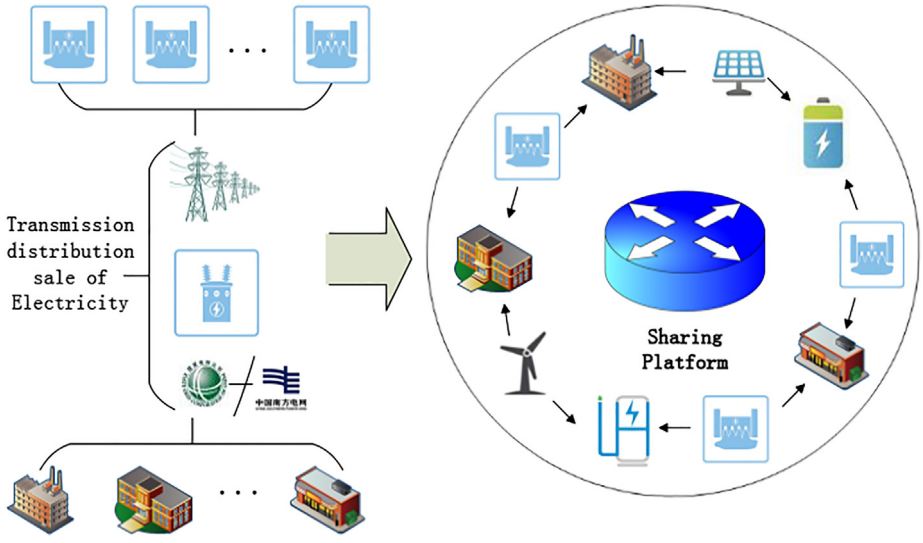


Fig. 16. Schematic diagram of the "shared platform" for electricity system.

also help to minimize the transaction costs, which is beneficial to both generating and consuming parties, so as to optimize the allocation of idle resources of hydropower. Also it requires the support of power storage technology.

In addition, whether centralized or decentralized wind power, solar power and other new energy sources can be introduced into this sharing platform to help the effective allocation of energy.

5.5. Policy design

Though China's "*Renewable Energy Law*" clearly stipulates that small hydropower belongs to renewable energy, hydropower has never been able to enjoy incentives policy like wind power and solar energy these years. At present, China's non water renewable energy incentive policy has caused the irrational social investment to a certain extent. Compared with the stoppage of domestic small and medium-sized hydropower during the "13th *Five-Year Plan*" period, the scale of wind power and photovoltaic installations has been expanding continuously throughout the country, with serious differences. And this is not conducive to the healthy development of the hydropower industry in the Yangtze River Basin under the market-oriented mechanism.

In the future, China should make reference to the establishment of green hydropower mechanism in developed countries in the world and improve the domestic green hydropower system. Secondly, government should define the reasonable status of hydropower and formulate corresponding incentive policy matching with the "*Renewable Energy Law*" to promote the healthy development of the hydropower industry in the Yangtze River Basin.

6. Conclusions

The Yangtze River Basin has rich water resources, but has not yet been fully exploited. During the past "11th *Five-Year*" and "12th *Five-Year*" period, China's hydropower development in the Yangtze River Basin has made great achievements, and played an important supporting role in the development of the Yangtze River Basin. The rapid development is also accompanied by many negative impacts. The Yangtze River basin means a lot for the Chinese government to fulfill its commitment of achieving 15% non-fossil fuels consumption by 2020 and 20% by 2030. The main conclusions are drawn as follows:

(1) At present, the development of hydropower in the Yangtze River basin is mainly limited to 3 factors: the negative impact on environment, the transmission and consumption problem, and the lack of incentive policies compared with other green energy sources. On the premise that these three restrictions are solved, the future development of the Yangtze River hydropower has great potential in energy structure adjustment and environmental protection.

(2) Hydropower will be the leader in green energy with the rich reserves. First, due to its many advantages over other green energy, like clean, manageable and maturity, hydropower will be put into the practice of energy structure adjustment as soon as possible. Second, since the technical exploitability of hydropower resource in the Yangtze River basin accounts approximately half of China's reserves, the government should focus on developing the Yangtze River basin to improve the overall level of China hydropower.

(3) China is a country short of fossil fuels per capita. Over-reliance on fossil fuels in the past, especially coal, caused a lot of environmental problems. Hydropower of Yangtze River basin will replace fossil fuels as a green energy. Through appropriate measures, its negative impact will be minimized and it will also reduce the fog and haze, greenhouse gas emissions and show fully people the achievements in green energy utilization.

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